A STUDY OF HEAT-PRODUCTION AND HEAT-DISSIPATION IN THE NORMAL AND FEBRILE STATES.[1]

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(From Private Laboratory of Dr. Isaac Ott.)

IT is a well-known fact that there is a diurnal rhythm in the growth of plants. They grow at night and remain inactive during the day.

M. Fredericq, on studying the absorption of oxygen by a normal man from 8 A. M. to 7 P. M. found two maxima—at 10 A. M. and 3 P. M. Upon a starved man these maxima did not exist, but the curve fell regularly.

Prof. Jürgensen has shown the existence of a diurnal rhythm in the temperature of man. The temperature reaches its maximum at 9 P. M. and its minimum at 7 A. M. He divides the 24 hours into two periods—the diurnal from 7 A. M. to 9 P. M. (the mean temperature being 99.2° F.) and the nocturnal from 9 P. M. to 7 A. M. (the mean temperature being 98.49° F.). He found too that this rhythm is present in fever, and is not affected by cold baths, starvation or muscular exercise.

Prof. H. C. Wood, in his work on "Fever," says: "There probably exists a rhythm of heat-production and heat-dissipation, the maximum and minimum of which occur synchronously with the maximum and minimum of animal temperature."

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[1] This thesis was awarded the Medical News Prize of University of Penna., 1890.

P. Langlois[2] made calorimetrical experiments on infants from 8 A. M. to 5 P. M., and found the heat-production attained its maximum at 3 P. M.

This is all the work that has been done on this subject to the best of my knowledge. This paper gives the results of experiments on rabbits, cats and dogs, showing the heat-production and heat-dissipation during the 24 hours. At no time was the animal kept in the calorimeter longer than an hour. Several of the experiments were performed with the improved calorimeter of this laboratory, whose error is only 5.4%. The observations were all made either four or six hours apart, so that the calorimeter could not bring the heat-dissipation into an abnormal condition. That there is much more heat produced in an animal after a meal than before, although the temperature remains the same, is a well-known fact. The heat-production of an animal is probably increased 35%-40% by the ingestion of food.[3] In order to eliminate any such influences, the animal was starved three days before the experiment began. Prof. Chittenden, of Yale, starves his animals three days in order that all food-stuffs taken into the organism might have time to be assimilated and eliminated. Three days seem ample time for the disappearance of food, so that in these experiments all the metabolic changes by which heat was produced took place in the stored-up material of the organism. Strong, healthy rabbits were used, and when possible, white ones, for they seem to be more susceptible to any changes in heat-regulation than do black ones. This fact has been pointed out by Prof. Wm. H. Welch.[4] The first three experiments lasted 48 hours. The heat-production decreased steadily toward the end of the experiment, caused, no doubt, by the long starvation. In order to avoid this, the other experiments only lasted 24 hours—the observations being taken every four hours.

Out of 20 days the maximum heat-production came at 7 A. M. three times, at 11 A. M. twice, at 3 P. M. five times, at 7 P. M. three times, at 11 P. M. four times, and at 3 A. M. three times, or ten times during the day and ten times at night.

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[2] Journal de L'Anatomie et de la Physiologie, Paris, 1887.

[3] Langlois, Journ. de L'Anat. et de la Physiol., Paris, 1887.

[4] Cartwright Lectures on The General Pathology of Fever.

The minimum occurs at 7 A. M. seven times, at 11 A. M. four times, at 3 P. M. once, at 7 P. M. three times, at 11 P. M. twice, and at 3 A. M. three times, or twelve times during the day and eight times at night.

The minimum came at 7 A. M. most often, but in five of these cases the experiments ended at that hour, and as the animal had been starved four days, it is obvious why the minimum should occur at that hour.

In the experiments in which the same animal was used twice, the maximum and minimum did not appear twice at the same time.

These results seem to prove the non-existence of any diurnal rhythm of heat-production and heat-dissipation.

The heat-production and heat-dissipation are not affected enough by external circumstances to produce any diurnal rhythm, but being under the control of a nervous mechanism, and having for their one great object the maintenance of temperature, they run a very unsteady course, being high at one time and low at another. Of all external circumstances which influence heat-production and heat-dissipation, external temperature seems to have more effect than any other. Prof. Richet[5] made 110 experiments to find the relation of external temperature to heat-production. He found a maximum heat-production when the external temperature was about 55.4°–57.2° F., and any temperature above or below this point decreased the heat-production.

We find the maximum temperature at 7 A. M. once, at 11 A. M. once, at 3 P. M. once, at 7 P. M. fourteen times, and at 11 P. M. three times, or three times during the day and seventeen times at night.

The minimum came at 7 A. M. eight times, at 11 A. M. seventeen times, at 3 P. M. twice, at 7 P. M. once, and at 11 P. M. twice, or seventeen times during the day and three times at night.

These results show a distinct rhythm of temperature, the maximum occurring in the evening (7 P. M.–11 P. M.) and the minimum in the morning (7 A. M.–11 A. M.). This rhythm in the rabbit, cat and dog is the same as Prof. Jürgensen found in man.

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[5] Acad. des Sciences, June, 1885.

The maximum and minimum of heat-production and heat-dissipation do not occur synchronously with the maximum and minimum of animal temperature. The two are entirely independent of each other.

Krieger has shown when the individual sleeps during the day and works during the night the typical course of the temperature is reversed. This statement has been confirmed by observations made at the suggestion of Prof. Huguenin, of Zürich, by Herr Buchser, an engineer of Rodi, who is accustomed to sleep during the day and work at night. As his tables show, his morning temperature oscillates between 37° and 37.5° C., while the evening record is between 36.6° and 37° C., averaging 36.8°. Maurel ascribes this vesperal rhythm to three causes — food, light and movement—and of these food is the most important. This factor is totally disproved in my experiments, as the animals had fasted three days, yet the vesperal exacerbation ensued. The worker at night reverses this rhythm, and here light could not be the factor, unless it is the artificial light, which would be hardly sufficient. From these results the conclusion ensues that it must be due to an action of the nervous system and probably to the activity of the thermotaxic centres.

This same absence of rhythm of heat-production was found in three experiments (lasting 48 hours) on animals that were constantly supplied with food. Here, as is to be expected, the variations were greater than in the starved animal. The same rhythm of temperature as exists in the starved animal was present.

To study the rhythm in fever it was necessary to produce a more steady fever than the septic fever. Each animal was starved two days. Then the centre of Eulenberg and Landois (at the junction of the cruciate and great longitudinal fissure) was destroyed and the animal starved another day. By this time the fever was fully established, and the experiment upon heat-production was begun.

The maximum came at 11 A. M. five times, at 3 P. M. three times, at 7 P. M. once, at 3 A. M. three times, or eight times during the day and four times at night.

The minimum came at 11 A. M. twice, at 3 P. M. twice, at 7 P. M. once, at 11 P. M. twice, at 3 A. M. twice, and at 7 A. M. three times, or seven times during the day and five times at night.

There appears here a slight tendency for the maximum to recur about mid-day or shortly after, but in some of these cases the experiments began at that hour, and besides, the experiments are entirely too few to warrant any statement that there is a diurnal rhythm.

The maximum temperature occurs at 11 A. M. twice, at 3 P. M. twice, at 7 P. M. five times, and at 7 A. M. three times.

The minimum comes at 11 A. M. three times, at 3 P. M. twice, at 11 P. M. three times, at 3 A. M. once, and at 7 A.M. three times.

These results show a much greater variation in the temperature of the fevered animal than in the normal animal, although it is probable that the same rhythm exists.

The heat-production and temperature are entirely independent of each other.

Below is given a table showing the average weight of each animal, the average heat-production and heat-dissipation and average rectal temperature of each experiment.

It will be seen that generally the greater the weight the greater is the heat production.[6] The animal temperature does not seem to have much effect on the heat-production, and the changes of the two are entirely independent of each other in all the experiments. The external temperature, however, undoubtedly affects the heat-production.

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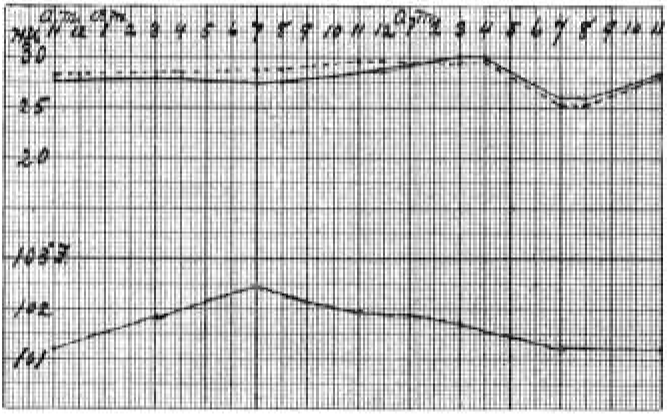
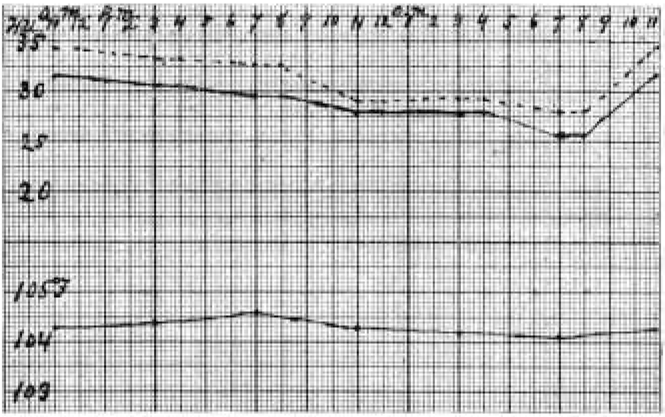
[6] Since this was written Prof. E. T. Reichert has published a paper showing the same result—University Medical Magazine, February, 1890.

	Average Wt., lbs.	Average H. P.	Average H. D.	Average H. T.
Ex. 1.—Starved Rabbit,	4.17	30.02	28.41	102.16
" 2.— " "	5.47	36.70	32.19	103.16
" 3.— " "	5.33	35.27	38.05	101.15
" 4.— " "	3.70	19.86	19.81	102.16
" 6.— " Cat,	3.02	22.63	23.23	101.33
" 7.— " "	4.91	24.91	26.21	101.00
" 8.— " Dog,	10.71	51.08	50.78	100.50
" 9.— " Rabbit,	3.33	28.06	28.92	102.13
" 10.— " "	2.77	17.47	18.48	101.46
" 11.— " Dog,	10.93	47.54	45.30	100.85
" 12.— " Rabbit,	2.68	21.57	22.59	103.03
" 13.— " Dog,	10.65	49.87	49.35	101.05
" 14.— " Rabbit,	3.27	22.22	23.08	101.95
" 15.— " "	3.44	21.64	22.31	102.60
" 16.— " "	3.42	17.42	18.07	102.05
" 17.— " "	3.10	24.73	24.62	103.30
" 18.— " "	3.62	23.03	24.06	101.33
" 19.—Fevered Rabbit,	4.25	27.01	24.19	103.22
" 20.— " "	5.02	36.71	33.10	103.68
" 21.— " "	5.47	35.09	29.46	103.10
" 22.— " Cat,	6.42	35.82	38.03	103.95
" 23.— " "	6.21	36.67	38.82	103.25
" 24.— " "	3.41	22.67	24.33	103.25
" 25.— " "	4.49	32.96	35.47	103.40
" 26.— " "	4.42	21.96	22.10	102.14
" 27.— " "	2.46	21.81	22.14	104.15
" 28.— " "	2.38	21.91	22.23	105.06
" 29.— " "	6.09	34.35	37.89	104.21
" 30.— " "	5.80	28.14	32.32	105.66
" 31.— " "	5.49	28.98	32.24	105.91
" 32.— " "	3.95	24.08	25.46	105.46
" 33.— " "	5.55	37.62	40.55	104.58

Below are two composite curves showing the average heat-production and heat-dissipation and rectal temperature. The continuous line represents heat-production, the dotted line heat-dissipation, and the line below the rectal temperature at the *beginning* of each observation, when it is not affected by being in the calorimeter. The temperature at the end of the hour is not given, so that what at first seems impossible is only apparent on comparing the changes of relation of heat-production and heat-dissipation with the changes of temperature.



Composite Curve showing the average of twenty experiments on starved animals.



Composite Curve showing the average of twelve experiments on fevered animals.